Report for 2002AK5B: Investigation of Fouling in Membrane Bioreactors for Wastewater Treatment

- Conference Proceedings:
  - Psoch, C.; Schiewer, S.: Air sparging in membrane bioreactors to enhance permeate flux and aeration. In: Proceedings of the 5th International Membrane Science and Technology Conference (IMSTEC), Sydney, 2003, (submitted)
  - Psoch, C.; Schiewer, S.: Strategies for enhanced performance of wastewater treatment in membrane bioreactors. In: Proceedings of ASCE/EWRI World Water & Environmental Resources Congress, Philadelphia, 2003.
- Other Publications:
  - Psoch, C.; Schiewer, S.: Fouling reduction by air sparging in synthetic wastewater filtration. 14th annual meeting, North American Membrane Society (NAMS), Jackson Hole, 2003 (oral presentation, poster and abstract).
  - Psoch, C.; Schiewer, S.: Air sparging in membrane bioreactors for oxygenation in wastewater treatment. 14th annual meeting, North American Membrane Society (NAMS), Jackson Hole, 2003 (oral presentation, poster and abstract).

Report Follows:

Problem and research objectives

Alaska's ecosystems are sensitive to disturbances such as water pollution. Due to the cold temperatures, organic pollutants still present in the discharged wastewater are degraded at a much slower pace than in warmer climates. Therefore, especially in protected areas or ecosystems already exposed to heavier pollution, the amount of pollutants discharged into surface waters has to be limited. Membrane bioreactors, with which a very high effluent quality can be achieved, can contribute to reduce aquatic pollution.

While the use of membrane bioreactors in wastewater treatment is rapidly growing worldwide, this relatively new technique faces the problem of membrane fouling which is the main drawback of this process. Therefore it is necessary to undertake further investigations with the aim of reducing the problem of fouling in membrane bioreactors.

The goal of the proposed project is to provide knowledge that can help to reduce fouling in membrane bioreactors. The objectives were to

1. Design and construct a testing facility for an experimental study of fouling in membrane bioreactors, using synthetic wastewater.
2. Experimentally test methods to reduce fouling and investigate the effect of operating parameters on permeate flux and fouling, using this testing facility.

Methodology

The chosen method for fouling reduction was air sparging. . Gas sparging, i.e. injecting of air into the feed of the membrane to generate a gas liquid two phase cross flow, which induces a higher shear stress on the membrane surface, helps to fight the build up of a cake layer, thereby maintaining a stable permeate flux over longer time-periods.

For the bioreactor, an activated sludge tank with 80 liter was used. The synthetic wastewater and activated sludge were pumped with a submerged pump (Grundfos) to the external membrane module.

The polymer membrane (PCI) has a length of 1.20 m and a pore size of 0.2 µm. The module is made of five tubes each with an inner diameter of 6 mm, yielding a membrane surface area of 0.1 m^2. On each side of the module, the membrane tubes were extended through an acrylic rod. The acrylic extensions with drill holes in the same diameter as the membrane tubes served for the air supply and for observation of the flow pattern in the unit. Each tube features its own connection to the air supply, with separately adjustable air volume stream for the air sparging.

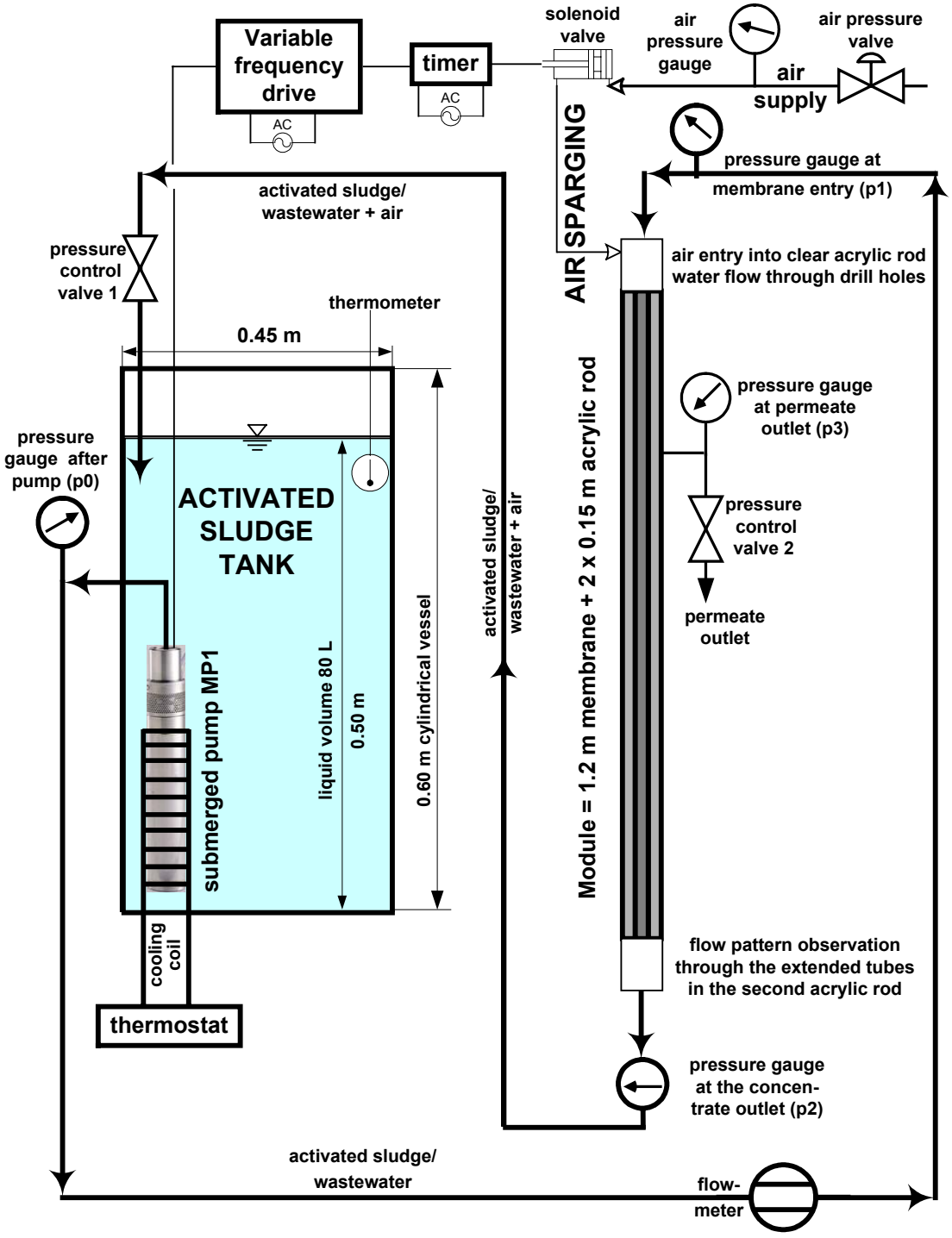

Figure 1. Scheme of the experimental setup

Principal findings and significance

The first set of experiments was performed with a synthetic wastewater based on dry milk powder. Milk in context with aeration shows a high tendency to build up fine foam. Thus, it was essential to add antifoam agents.

The influence of air sparging on wastewater filtration through membranes was investigated by comparing the flux in conventional operation to air sparged operation . The inclination of the membrane and the flow direction of air and water were varied as parameters. Three different setups have been investigated:

- upward vertical
- upward 45° inclined
- downward 45° inclined

For the wastewater filtration and for clear water a more stable flux with less decrease compared to the initial value could generally be observed when air sparging was applied, however the observed effect in maintaining the flux rate was not as pronounced as reported in the literature. Downward flow at a 45 ° inclination lead to a worse flux decline than straight or inclined upward flow, indicating that one of the latter configurations should be used. For further experiments, it was chosen to use vertical upward flow since it is more relevant for full scale applications.

To avoid problems related to foam production and side effects of antifoam substances, the second set of experiments was performed with a wastewater that contained glucose as the primary substrate. The reactor was first operated for a period of 11 days without air sparging, using a conventional aeration to supply oxygen to the bioreactor. A steady flux decline was noted for the first nine days, after which the flux stabilized reached a more stable value. On the 12th day air sparging was applied. Air sparging immediately yielded an increase in permeate flux. A higher flux was maintained in the following weeks even though the mixed liquor suspended solids concentration increased, which could potentially lead to increased fouling. Transmembrane pressure and temperature were maintained stable within a narrow range, so that the effect of these parameters was minimized. Gradual increase of the gas velocity showed that the highest flux rates were achieved when the superficial gas velocity approached the superficial liquid velocity. Thereby the permeate flux could be increased from about 3 L/m^{2}h without air sparging to almost 6 L/m^{2}h with air sparging.

An additional aspect of this set of experiments was to investigate to what extent air sparging could supplement or replace conventional aeration as a means of providing the necessary oxygen for the bioreactor. Comparing the oxygen saturation using only conventional aeration to the oxygen saturation using only air sparging yielded that a higher oxygen saturation could be achieved with air sparging even though a much lower air flow rate was used. One reason for this is the increased air contact time in the membrane loop. The results show that air sparging can serve a dual purpose of fouling reduction and oxygen supply, eliminating the need for conventional aeration of the bioreactor, which could lead to cost savings in industrial operation.

Chemical analysis of feed and permeate for standard wastewater parameters (COD, nitrogen compounds, phosphate) yielded that the bioreactor was effective in treating the wastewater, achieving about 90 % reduction in COD.